

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D.C. 20024

869 03075

SUBJECT: Entry Monitoring System Simulation  
Study Plan - Case 310

DATE: March 21, 1969

FROM: I. Bogner  
S. B. Watson

ABSTRACT

A study plan is presented for evaluating the performance of the Entry Monitoring System in three areas:

1. Nominal lunar-return entries of the type anticipated in Mission F using the SCS/EMS (11 simulations).
2. Off-nominal entries with emphasis on velocities between nominal lunar-return speeds and 40,000. fps. and ranges from 1200. to 2500. N.M. using the SCS/EMS (60 simulations).
3. Entries where the primary guidance has failed due to errors in scaling of sensed acceleration (24 simulations).

It is planned that the simulations will be flown by three members of the technical staff using standard backup procedures.

(NASA-CR-106878) ENTRY MONITORING SYSTEM  
SIMULATION STUDY PLAN (Bellcomm, Inc.) 21 p

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MEMORANDUM FOR FILE

1. PURPOSE

The study is to evaluate the two lunar EMS scroll patterns, with emphasis on off-nominal entry initial conditions and ranges. The patterns, shown in Figures 1 and 2, are designated:

FIGURE 1 - EMS Lunar Non-Exit Range Limit Pattern

FIGURE 2 - EMS Lunar 3500. N.M. Range Limit Pattern

The patterns, based upon a given design model, are designed to limit the minimum (skip) acceleration to 0.2g and limit the trajectory to a maximum range of 3500. N.M.

2. SCOPE

The simulations will cover three areas:

2.1 Support of Mission F

The entries listed in Table I will be simulated in support of entry studies planned for the North-American Mission Evaluator.

2.2 SCS/EMS Off-Nominal Entries

Entries, for the most part concerned with high speed and long ranges, will be equatorial from  $0.0^\circ$  latitude-- $0.0^\circ$  longitude. The entries are listed in Table II.

2.3 GNCS Failures

It is planned to fly entries in the Auto GNCS mode with sensed acceleration scaled by factors other than one. Current anticipated scaling is 0.5 and 1.5. Simulations planned are listed in Table III.

3. VEHICLE AND ENVIRONMENT CONFIGURATION

3.1 Weights and Inertias: Table IV

3.2 State of Switches and Displays: Table V

3.3 Aerodynamic Coefficients: Table VI - cg located to yield an  $L/D = 0.2912$ 3.4 Spacecraft L/D versus center of gravity location:  
Figure 3

3.5 Atmosphere: 1962 Standard

3.6 EMS velocity correction factor KD: 0.948

4. DATA RECORDING

The following data will be recorded for each run:

EIGHT CHANNEL RECORDER A

1. Altitude, h (ft.)
2. Longitude, LON (deg.)
3. Latitude, LAT (deg.)
4. Dynamic pressure x Area, QS (lbs.)
5. Inertial velocity, V (ft./sec.)
6. Angle of attack,  $\alpha_T$  (deg.)
7. Sin of aerodynamic resolution angle, Sin  $\phi_a$
8. Angle of Sideslip,  $\beta$  (deg.)

EIGHT CHANNEL RECORDER B

1. Sin Euler angle Phi, Sin  $\phi$
2. Cos Euler angle Phi, Cos  $\phi$
3. Euler Angle, Psi (deg.)
4. Euler angle, Theta (deg.)
5. Roll rate, p (deg./sec.)
6. Yaw rate, r (deg./sec.)
7. Cos roll angle, Cos R
8. Sin roll angle, Sin R

11x17 INCH X-Y PLOTTER

Total acceleration (g) versus EMS velocity (fps.) with an indication of when the pilot observed a tangency violation of the EMS patterns.

DIGITAL PRINTOUT

Terminal conditions at the end of the run with termination at 100,000. ft.

1. Total run time, t (sec.)
2. Aerodynamic force, FA (lbs.)
3. Altitude, h (ft.)
4. Longitude, LON (deg.)
5. Geocentric latitude, LAT (deg.)
6. Inertial velocity, V (ft./sec.)
7. Angle of attack,  $\alpha_T$  (deg.)
8. Altitude rate, HDOT (ft./sec.)
9. Roll command, ROLLC (deg.)

#### 5. INITIAL CONDITIONS

Nominal 400,000. ft. initial conditions as listed in the succeeding paragraphs will be used. In all cases the simulation IC's will be the 0.05G state corresponding to the 400,000. ft. nominal IC's. In all cases the initial roll orientation will be lift up. All runs will be identified by an IC number as follows:

1. Phase
2. Velocity
3. Flight-path angle
4. Range

##### 5.1 F Mission Support (Phase 1)

The Phase 1, IC's are identified by the basic quantities plus those that are parameters.

BASIC IC'S

h: 399,722. ft.

LON: 0.0°

LAT: -18.31514°

AZ: 98.5620°

<u>Target/Range</u>	<u>1350. N.M.</u>	<u>2500 N.M.</u>
LON	23.7087°	44.03°
LAT	-20.2493°	-18.68°

PARAMETERS

<u>Digit 2:</u> <u>Vel. (fps)</u>	<u>Digit 3:</u> <u>γ (°)</u>	<u>Digit 4:</u> <u>Target Range</u> <u>(N.M.)</u>
1) 36,210.494	1) -5.6°	1) 1350.
2) 40,000.	2) -6.49°	2) 2500.*
	3) -7.0°	

5.2 Off-Nominal Entries (Phase 2)

<u>Basic IC's</u>	<u>Target</u>
LAT: 0.0°	LAT: +0.2°
LON: 0.0°	
h: 400,000. ft.	
AZ: 90.°	

PARAMETERS

<u>Digit 2:</u> <u>Vel. (fps)</u>	<u>Digit 3:</u> <u>γ (°)</u>	<u>Digit 4:</u> <u>Target Range</u> <u>(N.M.)</u>
1) 36,210.494	1) -5.6°	1) 1350.
2) 37,000.	2) -6.49°	2) 1200.
3) 38,500.	3) -7.0°	3) 1600.
4) 40,000.		4) 2000.
		5) 2500.

\*Run for V = 36,210.494 only.

5.3 Failure Model (Phase 3)BASIC IC'S

LAT: 0.0°  
 LON: 0.0°  
 h: 400,000. ft.  
 AZ: 90.°

PARAMETERS

<u>Digit 2:</u> <u>Vel. (fps)</u>	<u>Digit 3:</u> <u>y (°)</u>	<u>Digit 4:</u> <u>Target Range</u> <u>(N.M.)</u>	<u>Digit 5:</u> <u>Scaling</u>
1) 36,210.494	1) -6.49°	1) 1350.	1) +50%
2) 37,000.		2) 1600.	2) -50%
3) 38,500.		3) 2000.	
4) 40,000.			

6. CASE SCHEDULE

Prior to each new phase, pilot change and new day five familiarization runs may be made.

Based upon discussions in the previous paragraphs on the number of parameters the total number of runs planned are as follows:

<u>Phase</u>	<u>No. of Cases</u>	<u>No. of Pilots</u>	<u>Total Runs/Phase</u>
1	11	3	33
2	60	3	180
3	24	3	<u>72</u>
		TOTAL	285

#### 7. SIMULATION ACCURACY AND REPEATABILITY

Each morning two dynamic system checks will be run.

1. Full lift up from earth orbital speed.
2. Spinning entry from a supercircular velocity.

The termination latitude and longitude for the rolling entry should be accurate to  $\pm 0.02^\circ$  and  $\pm 0.1^\circ$  respectively.

The impact latitude and longitude for the lift up run should be accurate to within  $\pm 0.2^\circ$ .



I. Bogner

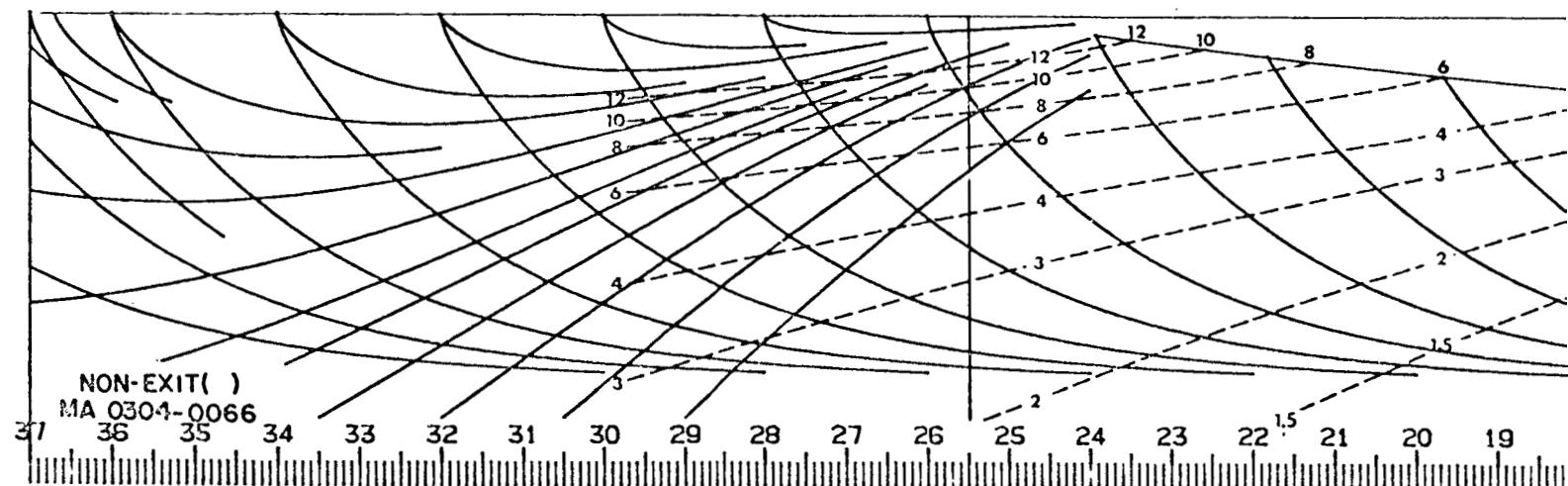


S. B. Watson

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Attachments

FIGURE 1 - EMS LUNAR NON-EXIT RANGE LIMIT



MIT PATTERN (7/22/68)

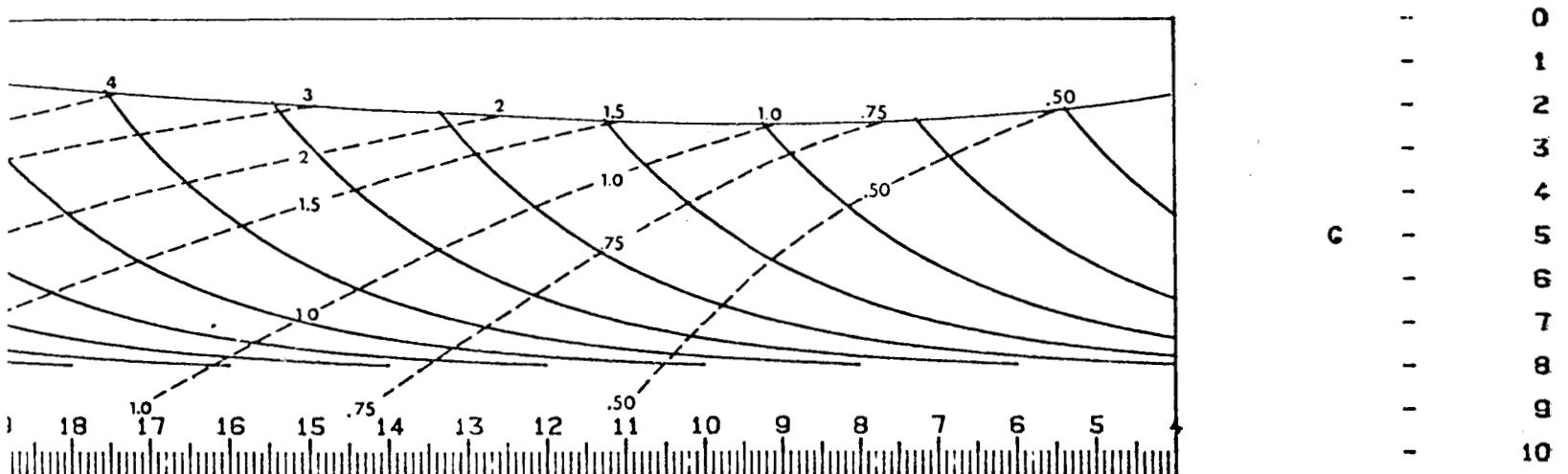
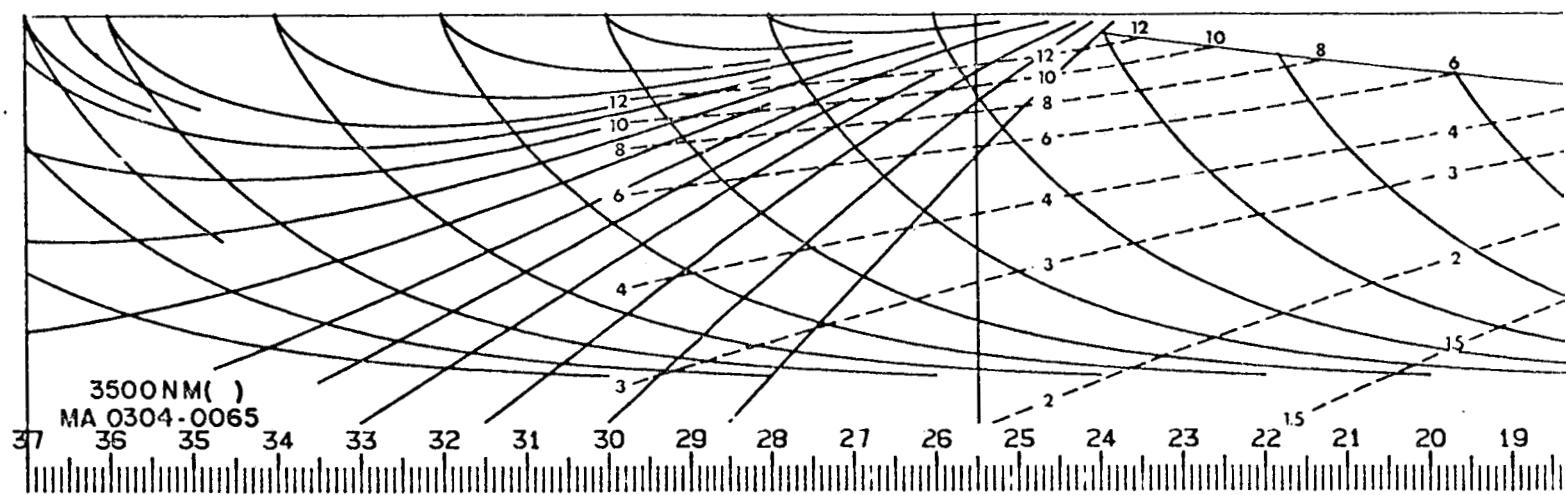
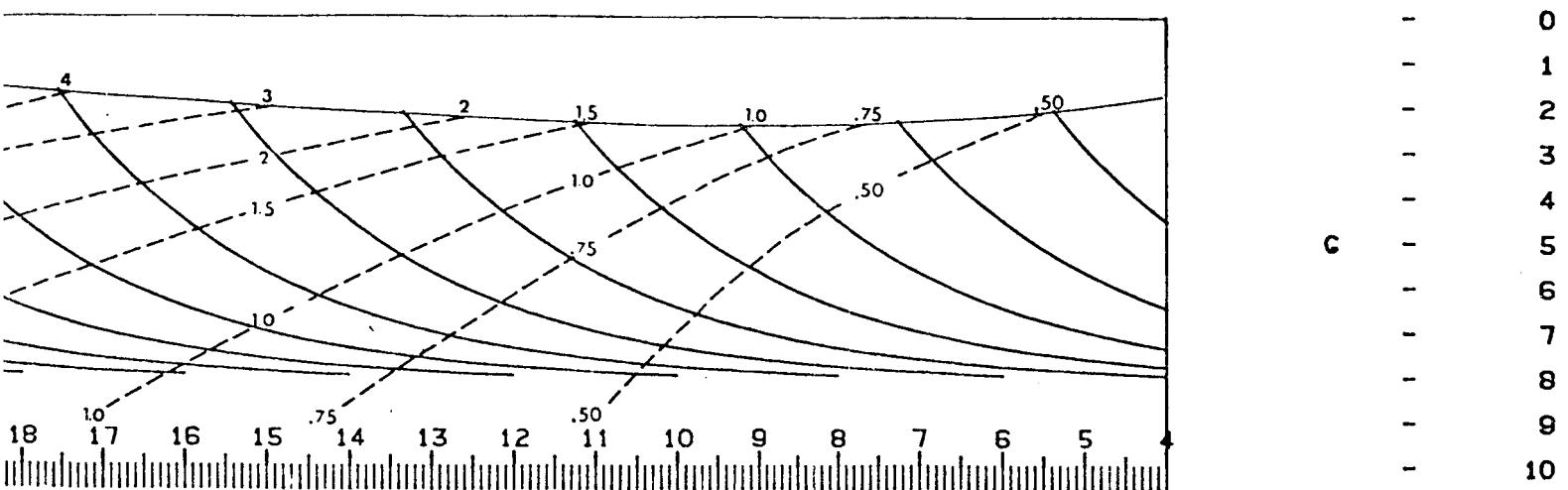
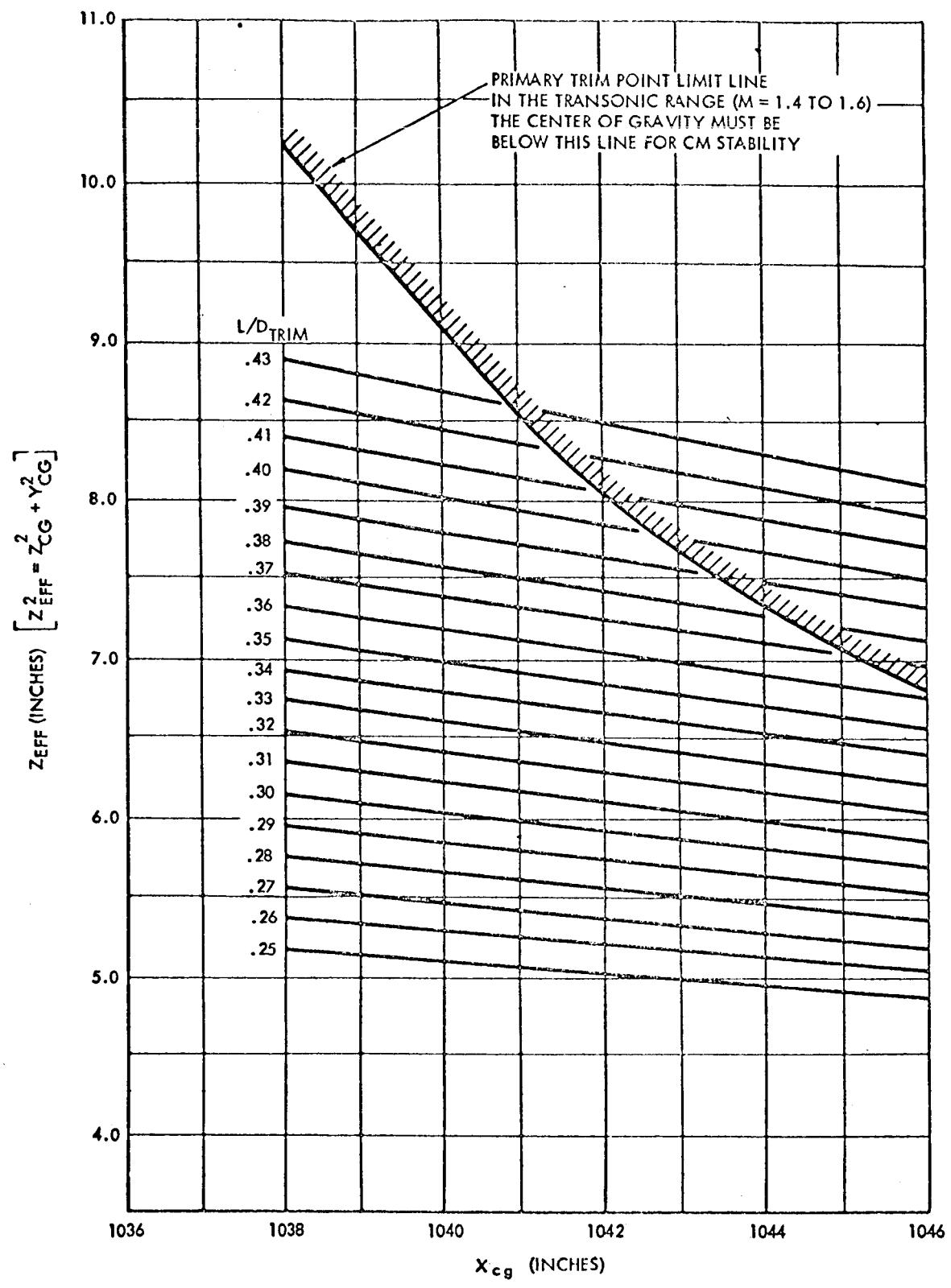


FIGURE 2 - EMS LUNAR 3500 NM RANGE LIMI



T PATTERN (7/22/68)





NOTE: BASED ON NOMINAL DATA IN TABLE 6-1 FOR  $M \geq 29.5$ .

**Figure 3.** Command Module Without Protuberances, Trim Lift-to-Drag Ratio Versus cg Location

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TABLE I - Entries in Support of F Mission

<u>Control Mode</u>	<u>Velocity (fps.)</u>	<u>Range (N.M.)</u>	<u>Flight-path Angle (deg.)</u>	<u>Failure Mode</u>
1. Auto GNCS	36210.494(Nom)	1350. (Nom)	-6.49 (Nom)	
2. Manual GNCS	36210.494	1350.	-6.49	
3. SCS/EMS	36210.494	1350.	-6.49	EMS Ranging
4. Auto GNCS	36210.494	2500.	-6.49	
5. SCS/EMS	36210.494	2500.	-6.49	EMS Ranging
6. Auto GNCS	40000.	1350.	-6.49	
7. Auto GNCS	40000.	1350.	-7.0	
8. Auto GNCS	40000.	1350.	-5.6	
9. SCS/EMS	40000.	1350.	-6.49	EMS Ranging
10. SCS/EMS	40000.	1350.	-7.0	EMS Ranging
11. SCS/EMS	40000.	1350.	-5.6	EMS Ranging

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TABLE II - Off-Nominal Entries

Velocity (fps.)	Range (N.M.)	Initial Flight-path Angle (deg.)		
		Shallow	Nominal	Steep
1. 36210.494	1350.	-5.6	-6.49	-7.0
2. 36210.494	1200.	-5.6	-6.49	-7.0
3. 36210.494	1600.	-5.6	-6.49	-7.0
4. 36210.494	2000.	-5.6	-6.49	-7.0
5. 36210.494	2500.	-5.6	-6.49	-7.0
6. 37000.	1350.	-5.6	-6.49	-7.0
7. 37000.	1200.	-5.6	-6.49	-7.0
8. 37000.	1600.	-5.6	-6.49	-7.0
9. 37000.	2000.	-5.6	-6.49	-7.0
10. 37000.	2500.	-5.6	-6.49	-7.0
11. 38500.	1350.	-5.6	-6.49	-7.0
12. 38500.	1200.	-5.6	-6.49	-7.0
13. 38500.	1600.	-5.6	-6.49	-7.0
14. 38500.	2000.	-5.6	-6.49	-7.0
15. 38500.	2500.	-5.6	-6.49	-7.0
16. 40000.	1350.	-5.6	-6.49	-7.0
17. 40000.	1200.	-5.6	-6.49	-7.0
18. 40000.	1600.	-5.6	-6.49	-7.0
19. 40000.	2000.	-5.6	-6.49	-7.0
20. 40000.	2500.	-5.6	-6.49	-7.0

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TABLE III - Entries With GNCS Failing in Sensed Acceleration

<u>Velocity (fps.)</u>	<u>Range (N.M.)</u>	<u>Initial Flight-path Angle (deg.)</u>	<u>Failure</u>
1. 36210.494	1350.	-6.49	$\pm$ 50% scaling in sensed acceleration
2. 36210.494	1600.	-6.49	
3. 36210.494	2000.	-6.49	
4. 37000.	1350.	-6.49	
5. 37000.	1600.	-6.49	
6. 37000.	2000.	-6.49	
7. 38500.	1350.	-6.49	
8. 38500	1600.	-6.49	
9. 38500	2000.	-6.49	
10. 40000.	1350.	-6.49	
11. 40000.	1600.	-6.49	
12. 40000.	2000.	-6.49	

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TABLE IV - Mass Properties of CM Prior to Entry

Weight	12121.5	Lbs.
Mass	376.75	Slugs
$X_{c.g.}$	1040.9	In.
$Y_{c.g.}$	0.0	In.
$Z_{c.g.}$	5.803	In.
$I_{xx}$	5817.0	Slug-Ft. <sup>2</sup>
$I_{yy}$	4985.0	Slug-Ft. <sup>2</sup>
$I_{zz}$	4506.0	Slug-Ft. <sup>2</sup>
$I_{xy}$	46.6	Slug-Ft. <sup>2</sup>
$I_{xz}$	-403.0	Slug-Ft. <sup>2</sup>
$I_{yz}$	27.4	Slug-Ft. <sup>2</sup>

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TABLE V - Desired Status of Operational Displays,  
Switches, and Controls at Beginning of Run

A. EMS

1. .05g light	off
2. Corridor indicator light	off
3. G-V plotter assembly G V	0.0 Value from voice link.
4. Roll attitude indicator	up
5. RTG display	Value from voice link.
6. Mode selector switch	Entry

B. DISPLAYS

1. G meter	0.0
2. FDAI	
a. Rate needles	5/5
b. Attitude error needles	5/5
c. Ball	gimbal angles
d. Roll bug	0.0

C. SWITCHES

1. FDAI SCALE	5/5 5/5
2. FDAI SELECT	1
3. FDAI SOURCE	ATT SET
4. ATT SET	GDC

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TABLE V - Continued

5.	MANUAL ATTITUDE ROLL	RATE CMD
6.	MANUAL ATTITUDE PITCH	RATE CMD
7.	MANUAL ATTITUDE YAW	RATE CMD
8.	LIMIT CYCLE	OFF
9.	ATT DEADBAND	MIN
10..	RATE	LOW
11.	DIRECT RCS	OFF
12.	SC CONT	SCS
13.	CMC MODE	AUTO
14.	ENTRY EMS ROLL	OFF
15.	ENTRY .05G	OFF
D.	CONTROLLER	
	CM Rotational Hand Controller (RHC)	DETENT

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TABLE VI - CM Static Aerodynamics  
Hypersonic Mach Range

$\eta$	Cos $\eta$	$C_A$	$C_N$	$C_M$ <sub>REF</sub>	$C_M$ <sub>AERO</sub>
110.1365	-.3442	-0.1879	.3686	-.2099	.03029
115.1365	-.4247	-0.3308	.3182	-.1610	.04635
120.1365	-.5020	-0.4706	.2709	-.1178	.05872
125.1365	-.5755	-0.6095	.2225	-.0770	.06799
130.1365	-.6446	-0.7335	.1983	-.0547	.07452
135.1365	-.7088	-0.8634	.1819	-.0410	.07753
140.1365	-.7675	-0.9794	.1687	-.0328	.07713
145.1365	-.8205	-1.0828	.1424	-.0194	.07339
150.1365	-.8672	-1.1763	.1202	-.0103	.06803
155.1365	-.9073	-1.2672	.0960	-.0016	.06096
160.1365	-.9405	-1.3452	.0748	.0033	.05204
165.1365	-.9665	-1.4138	.0526	.0083	.04258
170.1365	-.9852	-1.4611	.0305	.0144	.03127
175.1365	-.9964	-1.4840	.0115	.0129	.02039
180.1365	-1.0000	-1.4900	-.0035	.0137	.01142
185.1365	-.9960	-1.4840	-.0185	.0144	.00234

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TABLE VI - Continued

Reference Area =  $S = 129.3 \text{ Ft.}^2$

Reference Diameter =  $D = 154.0 \text{ In.}$

Moment Center:  $X_{\text{REF}} = 1141.25 \text{ In.}$

$X_{\text{AERO}} = 1040.9 \text{ In.}$

$Y_{\text{c.g.}} = 0.0 \text{ In.}$

$Z_{\text{c.g.}} = 5.803 \text{ In.}$

$L/D = .2912 \text{ In.}$

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From: I. Bogner  
S. B. Watson

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